[0047] First **38** and second **40** members are adjacent to magnetic-field generating device **42**, and disposed at least partially on opposing sides of magnetically-controllable medium **34**. Members **38, 40** each preferably include a highly magnetically permeable material, such as a magnetically soft steel such as AISI 1010, AISI 1018 or AISI 12L14 in order to act as pole pieces to produce a magnetic field across medium **34**, as indicated by flux lines **44**. Additionally, second member **40** is in communication with haptic interface device **26**, such that operator **22** moving the haptic interface device during energization of magnetic-field generating device **42** feels the changed resistance force generated between first **38** and second **40** members by magnetically-controllable medium **34**. Significant shear force resisting the relative movement of first member **38** and second member **40** can advantageously be obtained with a small amount of magnetically-controllable medium **34** between movable members **38, 40**. Thus, a variety of relative movements, such as linear, rotational, curvilinear, and pivoting, that include shear movement between two members can be controlled by a magnetically-controllable device according to the present invention.

[0048] Additionally, magnetically-controllable device **24** preferably contains substantially the entire amount of magnetically-controllable medium **34** at working space **36**. Any suitable means for containing medium **34** at working space **36** can be used. According to a preferred embodiment of the invention, means for containing magnetically-controllable medium **34** within working space **36** comprises an absorbent element **46**. Absorbent element **46** is a material that can take up and hold magnetically-controllable medium **34**, for example by wicking or capillary action. Absorbent element **46**, disposed between first member **38** and second member **40**, preferably has a matrix structure with open spaces for retaining magnetically-controllable medium **34**. While magnetically-controllable medium **34** is held within the spaces in absorbent element **46**, the material itself may or may not be absorbent. A complete description of such devices may be found in U.S. patent application Ser. No. 08/959,775 to Carlson filed Oct. 29, 1997 entitled "Controllable Medium Device And Apparatus Utilizing Same."

[0049] A particularly preferred absorbent element **46** is a sponge-like material, for example, an open-celled foam or partly open-celled foam. Suitable materials for making such a foam comprise polyurethane, rubber, silicone rubber, polyamide, neoprene, loner, melamine, polyimide high temperature foam, and metal foam. Additionally, other exemplary absorbent materials include felts, including felts mad of material such as Nomex® aramid fiber, polybenzimadazole fiber, Teflon® fiber and Gore-Tex® fiber, fiberglass wicking, and woven brake or clutch lining material. Other materials and structures are also suitable, such as a metal mesh, a brush, or a flocked surface material.

[0050] Absorbent element **46** also beneficially allows for reduced tolerances between the components of magnetically-controllable device **24**, thereby reducing the cost to manufacture and assemble device **24**. In order to negate the affects of wear at the surface of absorbent element **46**, and to provide a robust design, it is desirable to have the material compressed between member **38, 40**. Absorbent element **46** may be utilized without any compression, but the material is preferably compressed between about 30% and 70% from a resting state to its installed state. Thus, by containing substantially the entire amount of controllable medium **34** at working space **36** and allowing for wear and tear of absorbent element **46**, the present invention avoids the need to provide a large quantity of medium, and the associated seals, bearings and containing devices of the prior art. Accordingly, the present invention reduces the tight tolerances formerly needed on all components.

[0051] Absorbent element **46** is preferably fixed to one of the relatively moving members **38, 40** to ensure that it remains disposed in the working space **36**. According to a preferred embodiment, absorbent element **46** is adhesively bonded using a pressure sensitive adhesive to one of the members. One preferred absorbent element **46** is polyurethane foam having a pressure sensitive adhesive on one side. The foam may be readily attached to one member by the adhesive. Alternatively, absorbent element **46** may be shaped so that it is held in place by the structure of the member, for example, a tubular shaped foam material may be fitted around a member as a sleeve. Finally, absorbent element **46** does not need to fill working space **36**.

[0052] Referring to FIGS. 2A-2B, magnetic-field generating device **42** preferably comprises at least one coil **48** formed of an electrically-conducting wire wound about a retainer **50**, such as a plastic bobbin or spool. The windings of wire forming coil **48** are wound such that energizing the coil with electricity produces an induced magnetic field, represented by flux lines **44**, that intersects magnetically-controlled medium **34**. The induced magnetic field is proportional to the electric current supplied to energize the coil **48**, such as from the output signal of computer system **28** and number of turns of wire. The wire forming coil **48**, as will be realized by one skilled in the art, may be selected from a broad range of electrically-conducting materials, depending on the range of the desired magnetic field strength, the range of desired electrical current, space constraints, and desired operating voltage. For example, wire may comprise materials such as copper, aluminum, gold, silver and the like. Similarly, the gauge of the wire and the number of windings within coil **48** are dependent upon the application, and can be determined by methods known by one skilled in the art.

[0053] Magnetic field generating device **42** may be adjacent first member **38** or second member **40**, but is preferably disposed within a recess **52**, such as annular recess shown, formed within one of members (shown within first member **38** in **FIG. 2B**). The lead wires **53 (FIG. 2A)** connecting to coil **48** are connected to controller **28** , which provides a signal **66'** (shown in detail in **FIG. 1A**) to energize the coil, as is discussed in further detail below. Because the wires **53** connecting coil **48** may be mounted to a moving member, there may be a need to restrict the movement of that member in order to avoid breaking the wire by excessive stretching, bending or rotation of the wires. Alternatively, means may be provided to enable a connection to controller **28** even with excessive linear, rotational, pivotal or curvilinear movement. For example, a slip-ring connector, a wire take-up reel, and a coiled wire may be utilized to allow for great amounts of movement while maintaining a reliable connection. These alternatives are generally more costly, however, and thus are not as desirable for a cost efficient haptic interface system.

[0054] Referring to **FIG. 1A**, magnetically-controllable device **24** is preferably integrated with haptic interface device **26** and sensor **32** to comprise a haptic interface unit (as represented by the dashed line **55**). The haptic interface